Off-angle Thermal Spray Coating Deposition: Enabling Approach to Coat Small Internal Diameters

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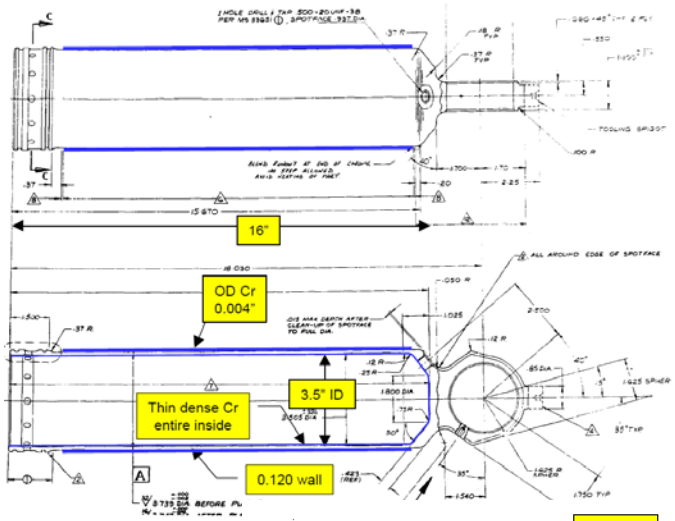
Technology need

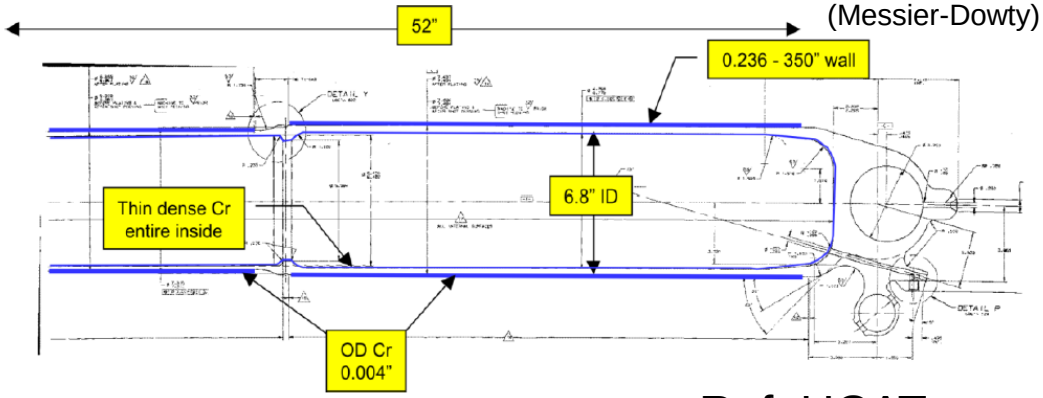
- **What technology is being used currently?**
  - Hard Cr plating (wear, corrosion prevention, improved lubricity in presence of lubricant)
  - Why do we need alternative technology?
    - Environmental/regulation problems – Hexavalent Cr is highly carcinogenic and is regulated
    - Thermal spray coating has longer service life
    - Cr plating getting more and more costly
    - Cr plating is very slow process
    - We are moving to future light weight
- **An example application**
  - Landing gear internal diameters
    - Down to 1” up to 7”
    - WC-CoCr and CrC-NiCr as coating materials

What we are trying to do?

- **Replacing the hard Cr plating in non-line of sight components employing thermal spray technique**



Landing gear actuator cylinder – (Messier-Dowty)



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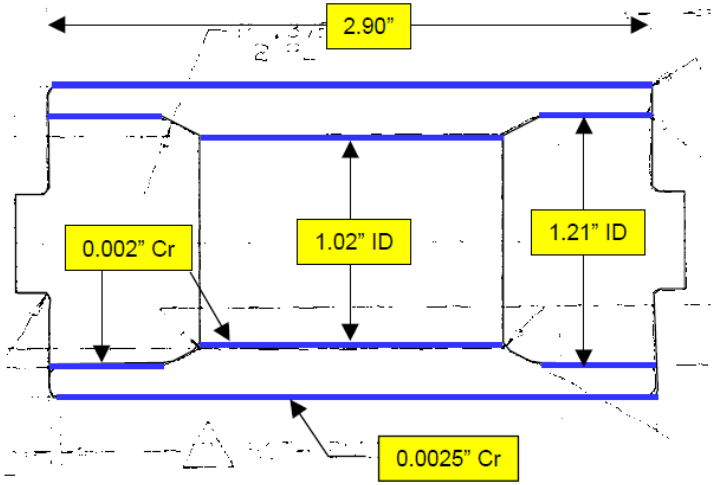
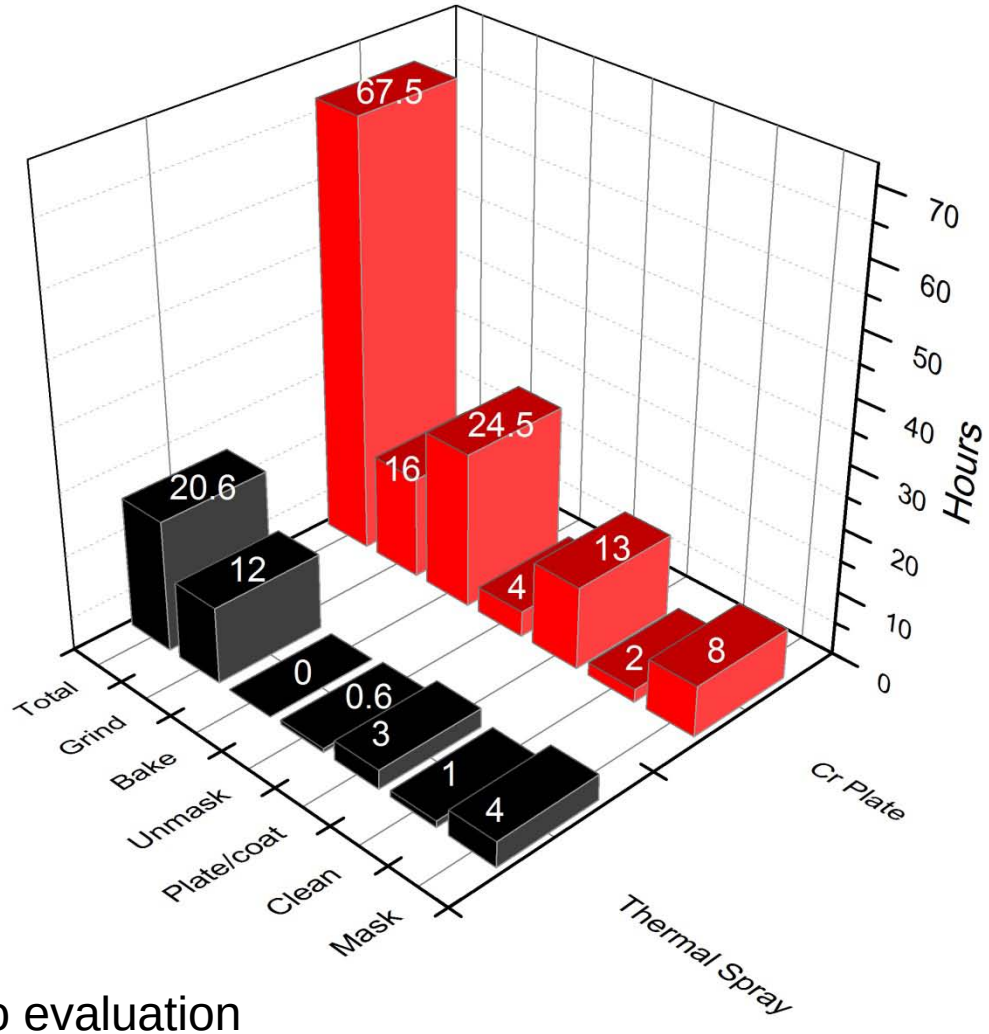


MLG shock strut piston (Messier-Dowty)

Ref: HCAT report

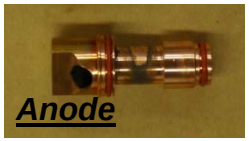
Cr plating Vs. thermal spray

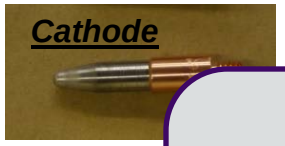


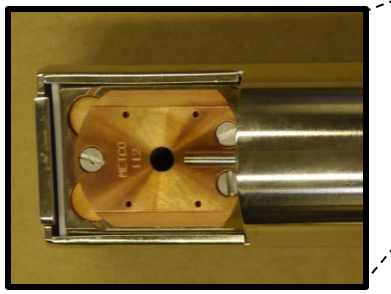
Ref: Sulzer Metco evaluation

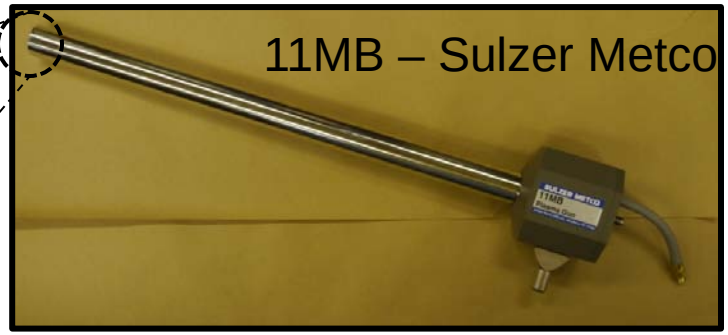
Solution#1: Internal diameter plasma torches (minimum 3.5” IDs)

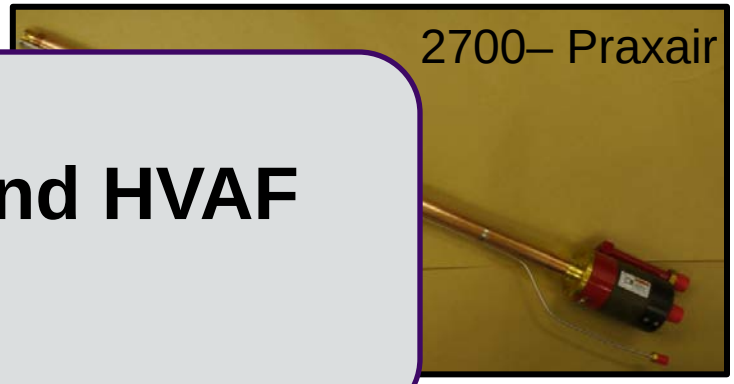
External feeding



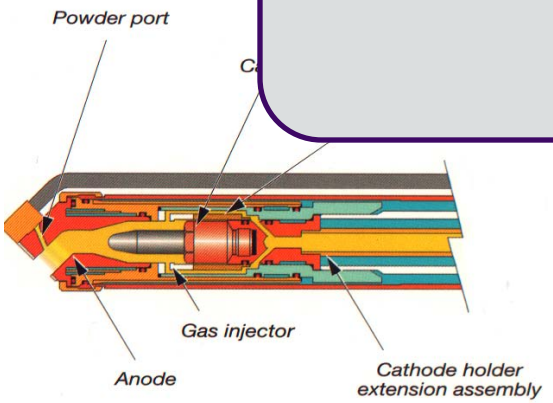






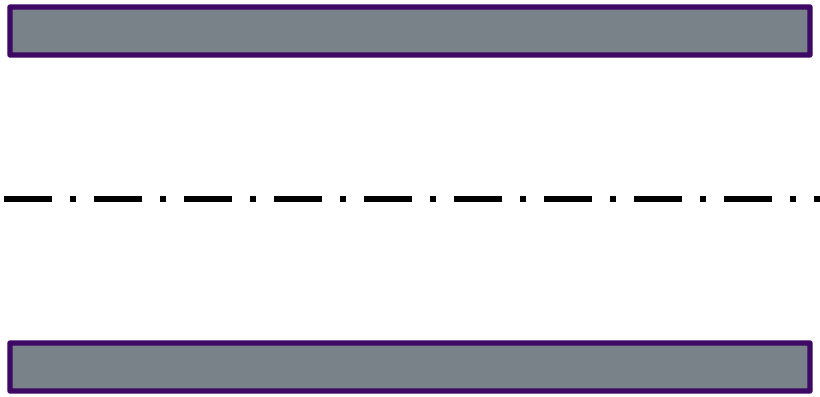


What about HVOF and HVAF systems?



Solution #2: Off angle HVOF spraying (less than 3.5” IDs)

Cross section of ID component

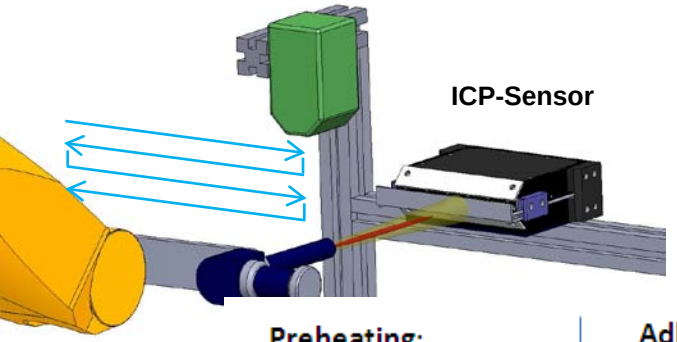


Off angle

Effect of different spray angles on:
Microstructure
Stresses
Mechanical properties
Performance

Normal spraying

Coating formation – Understanding the stress formation



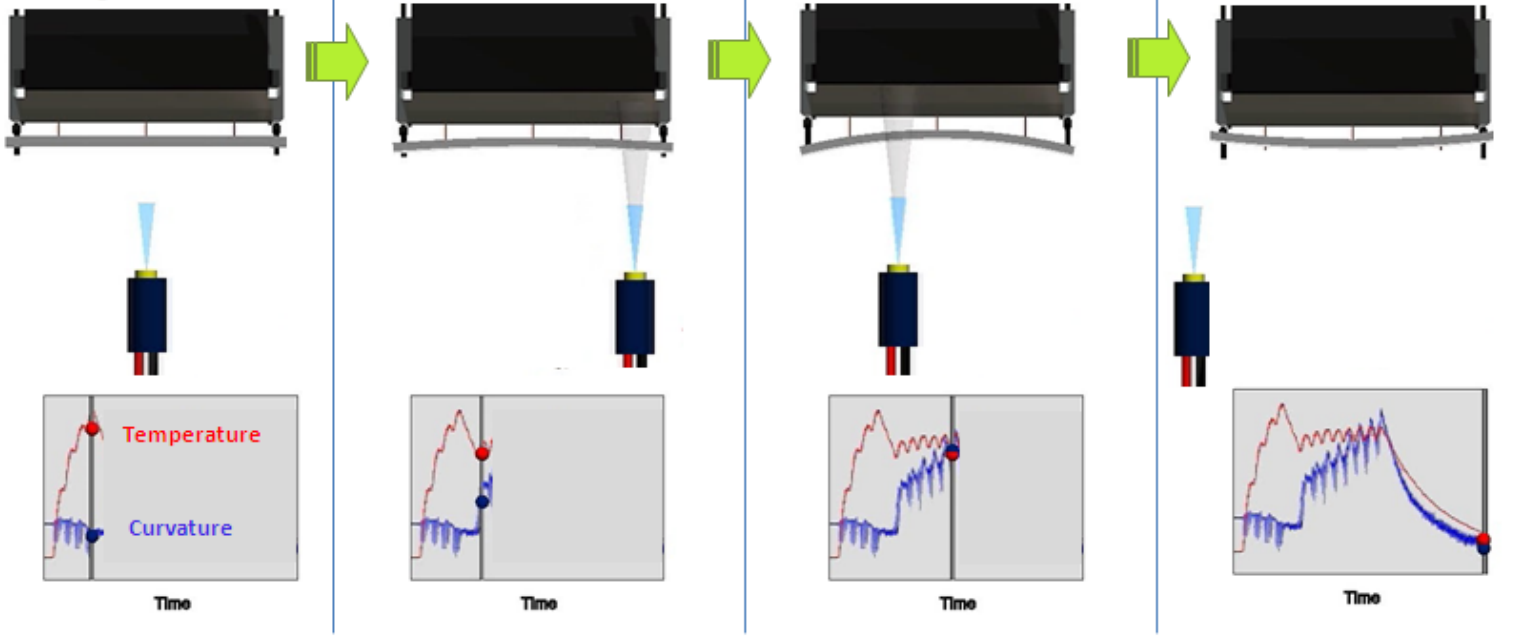
-Curvature is monitored by lasers at three points while temperature is measured by contact thermocouples.

Preheating:
Uncoated substrate, stress relief (from grit blasting) due to heating.

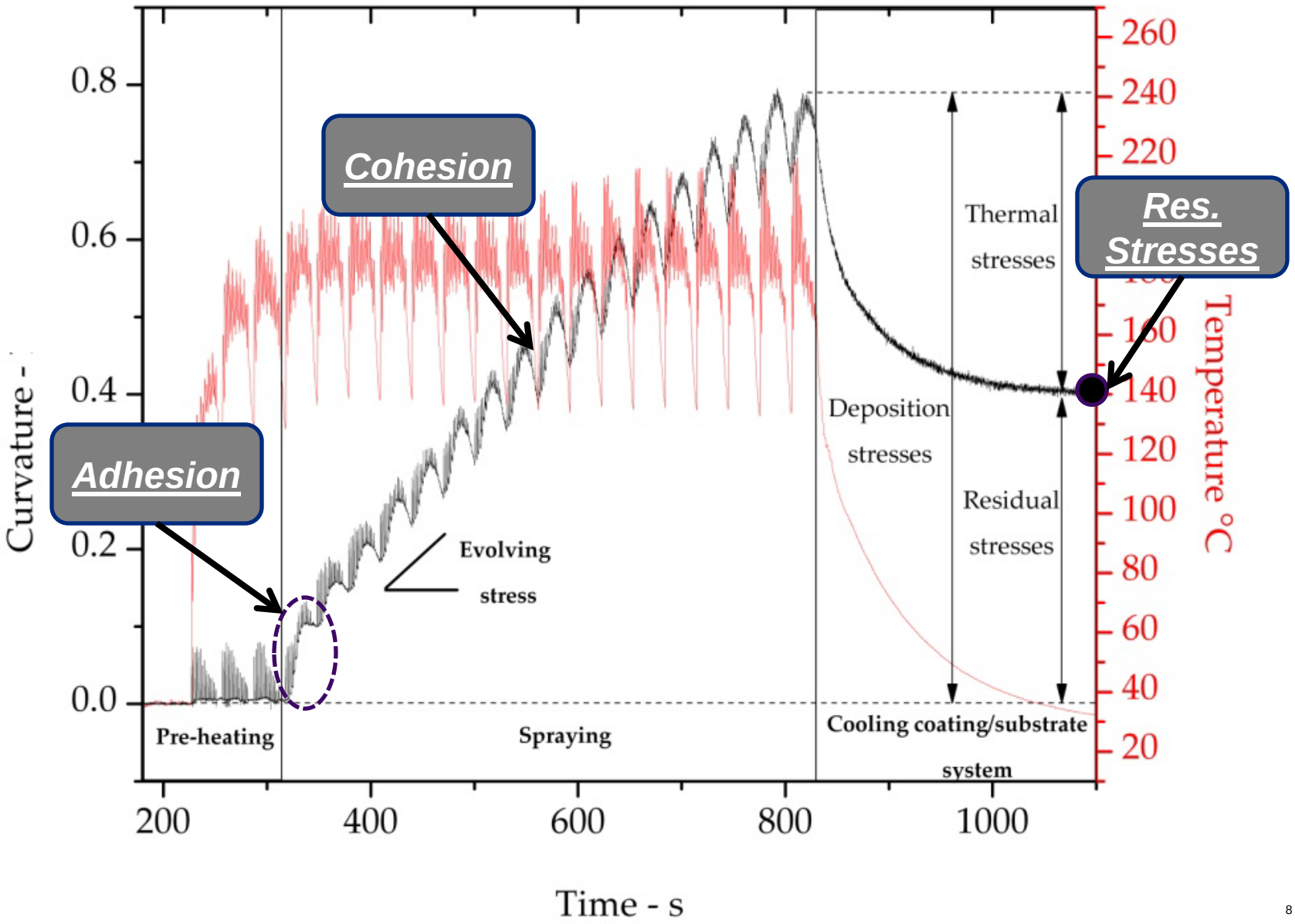
Adhesion Pass:
First pass, initial bending, better adhesion, coating pulls harder, retains more stress.

Evolving Stress:
Each layer shows similar residual stress, check consistency, cohesion and peening

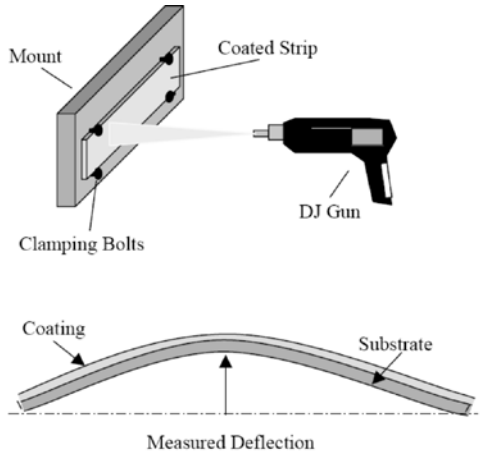
Cooling Curve:
Coating elastic modulus, non-linearity, stress-strain curve, and residual stress can be extracted.



Interpretation of ICP data

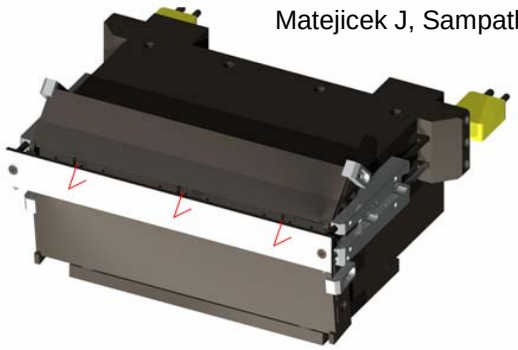


Almen Vs. ICP



Standard	Equi. Stress [Mpa]
Spec I	-120 to -480
Spec II	-240 to -600

ICP Sensor



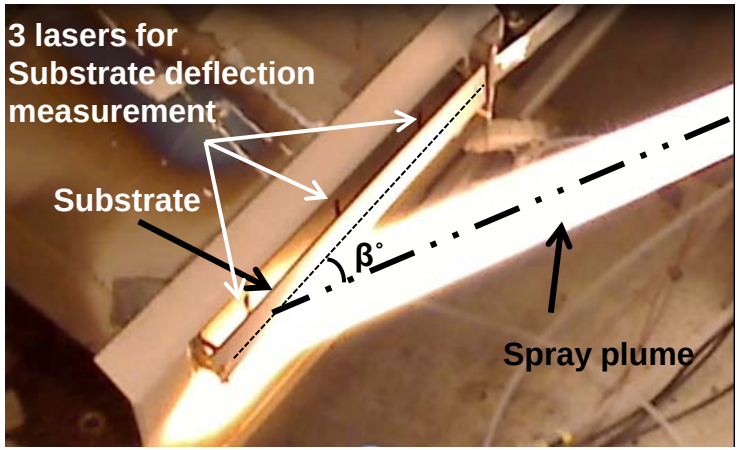
Matejicek J, Sampath S. US Patent 6,478,875.

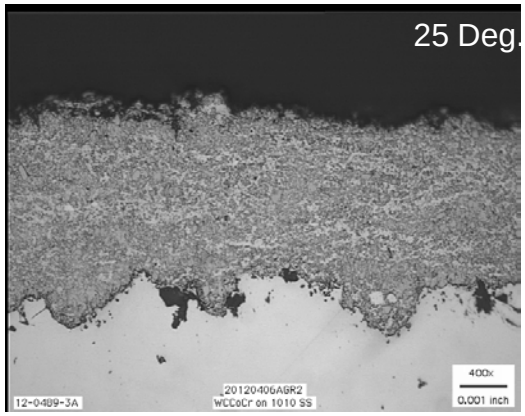
- No Evolution of the Stresses,
- No temperature history
- Non uniform stress distribution due to restraining
- Limited information to design coatings
- Only applicable to steel substrates
- Variables under no-control:
  - substrate temperature,
  - peening from grit-blasting,
  - holder type
  - deposition rates

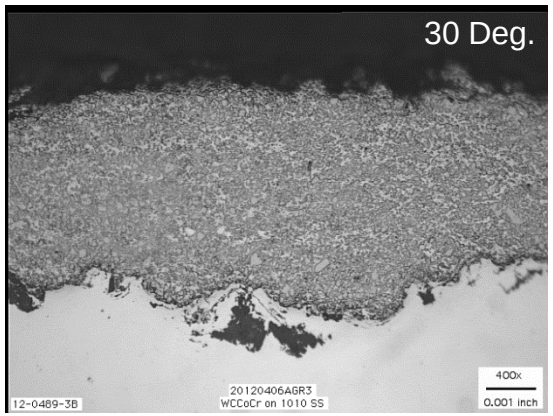
- Develops detail understanding of evolving of stress,
- Provides temperature history
- Uniform stress distribution
- Provides through thickness stresses within coating and substrate useful for coating design
- No limitation on substrates
- Can help to develop in depth understanding of following parameters on stresses:
  - substrate temperature,
  - Process variables,
  - Deposition rates

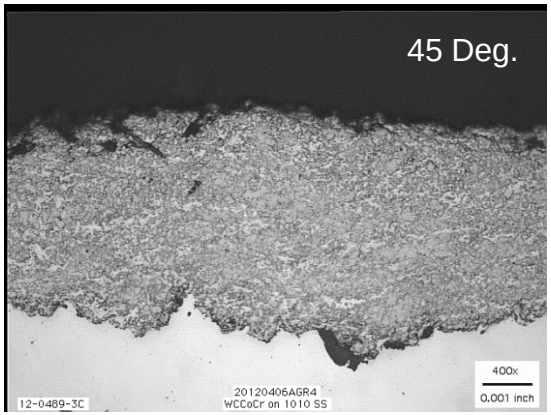
Acknowledgement: Prof. Sanjay Sampath, Stony Brook University

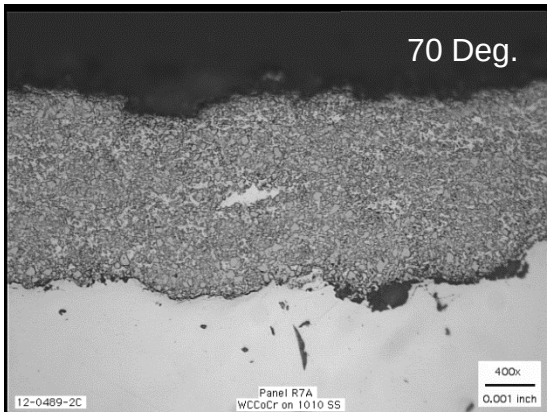
Off angle spraying: Enabling approach

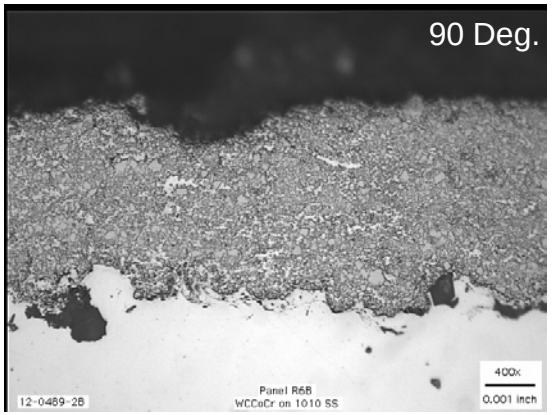






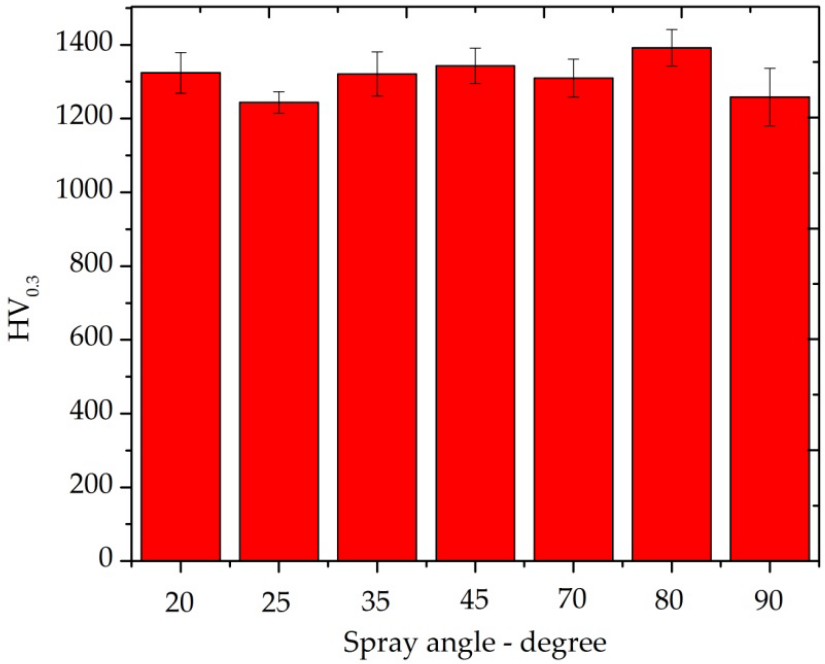






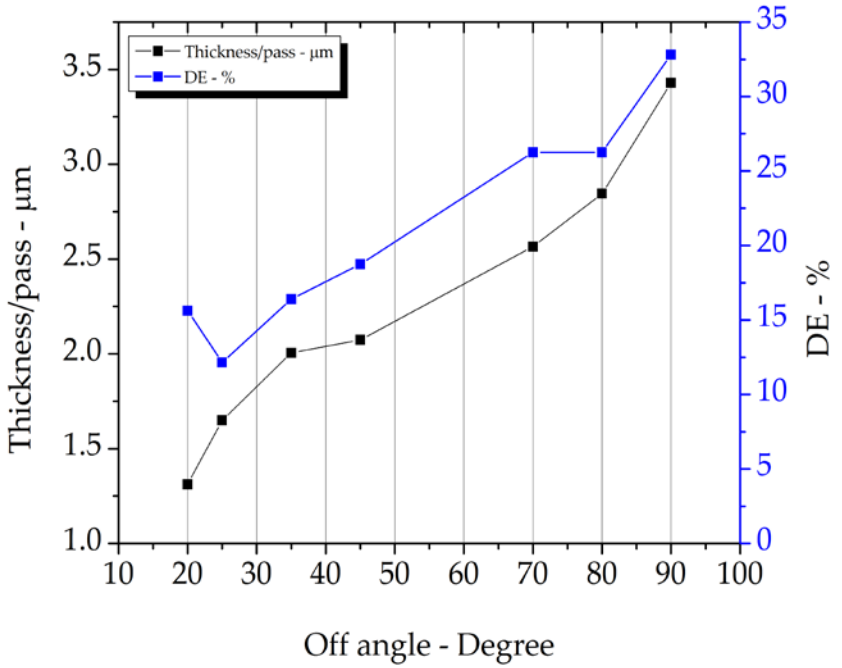
Spraying angle has no impact on the microstructure of coating.
Obtaining microstructure from different orientation is required.

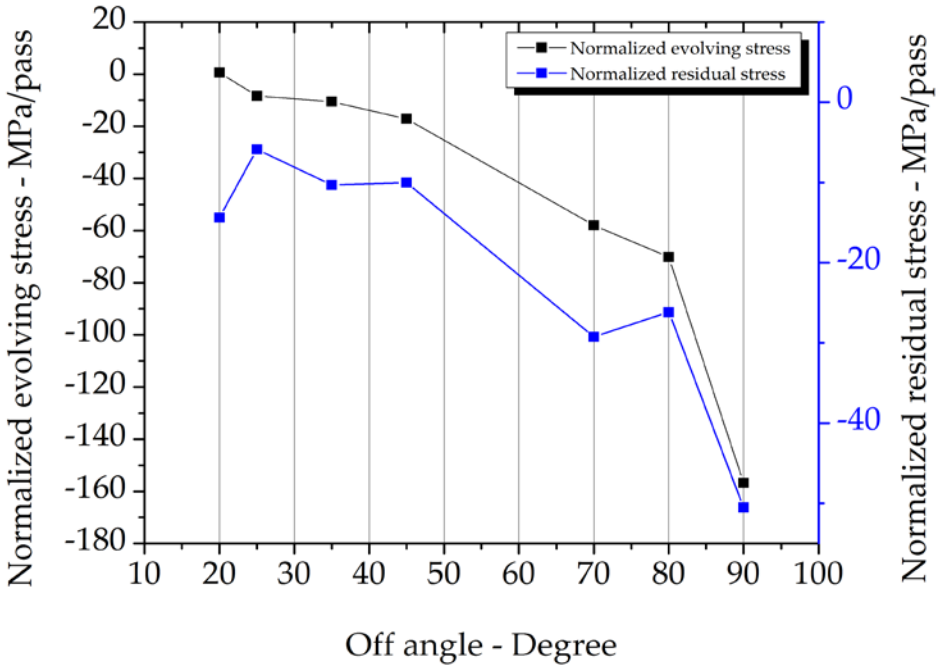
Off angle spraying: Enabling approach



Spray angle has no impact on the measured coating hardness. Obtaining microstructure from different orientation is required.

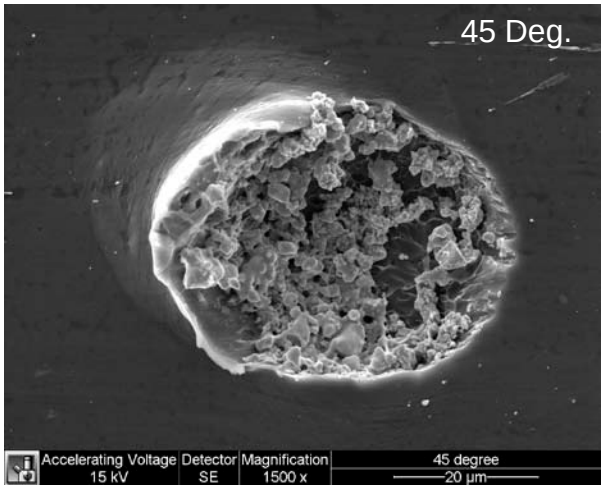
Off angle spraying: Enabling approach

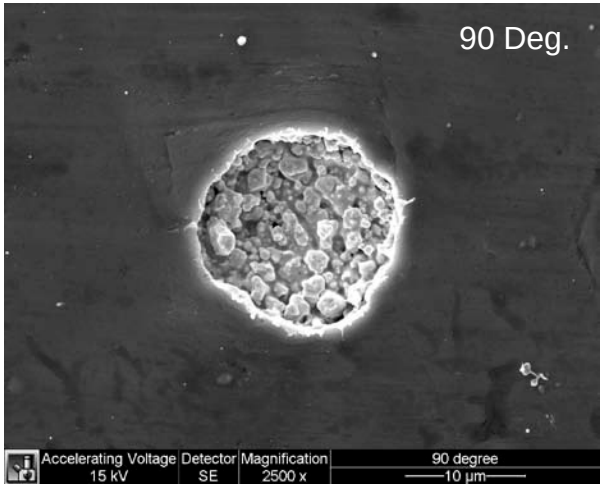


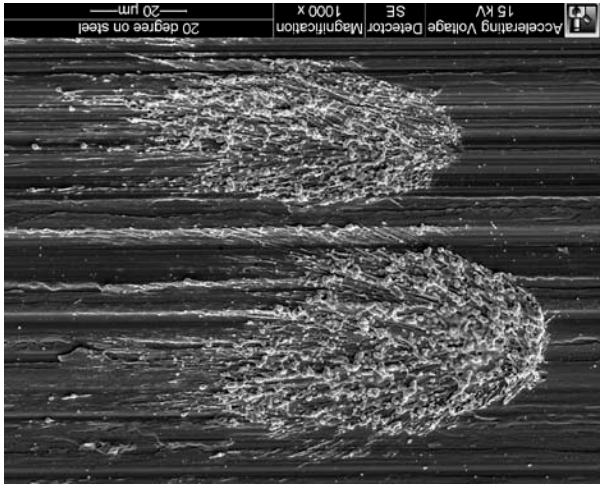


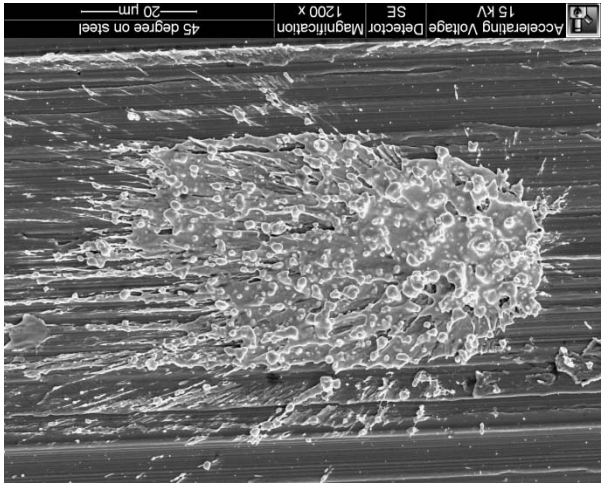
Off angle spraying: Enabling approach

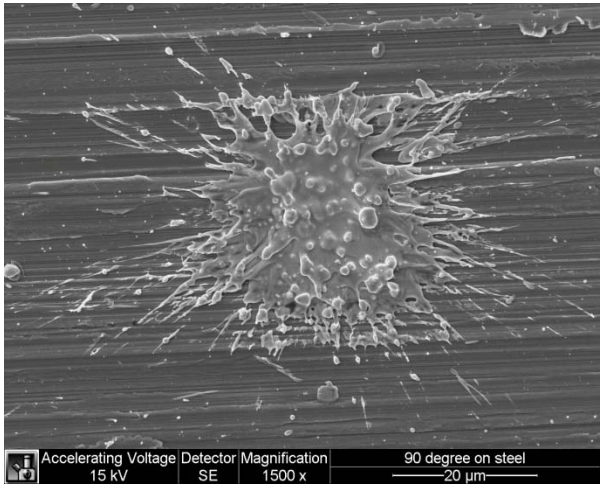
Increase in DE & peening











Conclusion

- **Coating stresses are highly sensitive to spray angle.**
- **Microstructure and hardness are not significantly affected by spray angle.**
- **It is hypothesized that spray angle increases the anisotropy of TS coating and further studies addressing the issues related to anisotropy is required.**